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Certified by

Jon W Dudas

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PROVISIONAL APPLICATION COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(b)(2)

Docket Number	11463-1	Type a Plus Sign (+) inside this Box –>	+

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TITLE OF THE INVENTION (280 CHARACTERS MAX.)

Multiple Coil for Enhanced Surface or Volume Imaging

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ENCLOSED APPLICATION PARTS (Check all that Apply)

X	Specification	Number of pages	4			Small Entity Statement
X	Drawing(s)	Number of Sheets	11			Other (specify)

METHOD OF PAYMENT (Check One)

	A check or money order is enclosed to cover the Provisional filing fees	Provisional Filing Fee Amount ($)	$ 160.00
X	The Commissioner is hereby authorized to charge filing fees and any deficiency in the filing fees and credit to our Mastercard Account Form PTO-2038 is attached		
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The invention was made by an agency of the United States Government or under contract with an agency of the United States Government. __X__ No

Date: 25 July 2003

Respectfully submitted,

J. Wayne Anderson
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Regn No. 28,158

Enclosures
:yw

__No__ Additional inventors are being named a separately numbered sheets attached hereto.

PROVISIONAL APPLICATION FILING ONLY

Multiple Coil for Enhanced Surface or Volume Imaging

TECHNICAL FIELD OF THE INVENTION

This invention relates to certain advances in surface or volume array coil designs for Magnetic Resonance Imaging (MRI) and Spectroscopy (MRS).

Surface and volume coils are used for both magnetic resonance imaging (MRI) and magnetic resonance spectroscopy (MRS). Presently, surface loop coils are used to produce a certain signal-to-noise ratio (SNR) at a particular depth of interest within a sample. The dimension and geometry (square, circular, hexagonal, rectangular or diamonds) of the loop element is optimised for that depth (figure 1). A second "butterfly" element (figure 2) can be added on top of the "loop" (figure 3) and combined into a single channel using an optimised combiner to increase the SNR at the depth of Interest typically by 20%-30% [1]. This is because the loop and butterfly are naturally isolated (decoupled) from each other so that no noise correlation exists. This gives rise to the well-known quadrature SNR gain. For that depth of interest, this technique is thought to maximize the SNR for a single channel. No other "stacking" of array elements was thought of to increase SNR at the depth of interest. To increase field of view (FOV) in the long dimension additional inductively decoupled loop-butterfly elements are placed along the long axis and fed into separate receivers. The SNR is lower in between the array elements in the long dimension where the "overlap" occurs. This is related to the SNR falloff of the individual array elements. Closing the gap between array elements would not increase SNR due to added noise coupling. A surface array has been published that does provide SNR gain nearer to the surface and may provide parallel imaging benefits, but does not significantly increase SNR at the depth of interest significantly [2]. The problem with this design is that naturally decoupled array elements were made by decreasing the sizes of the constituent parts.

An object of the present invention is to provide a new design for an array coil that improves the homogeneity and SNR at a desired depth of MRI and MRS.

SUMMARY OF INVENTION

An embodiment of the present invention combines stacking the traditional loop-butterfly array elements with twisted loop and twisted butterfly elements. The footprints i.e. the dimensions and the alignment of the twisted elements are chosen such that the elements are naturally isolated from both the loop and the butterfly, and such that a SNR gain is achieved at the depth of interest. Many higher order twisted array elements can be added that are also naturally decoupled from the loop-butterfly elements. The dimensions can be chosen to produce significant SNR at the depth of interest.

BRIEF DESCRIPTION OF DRAWINGS

Figure 1   an embodiment for a 1- lobe loop layout (prior art)

Figure 2   an embodiment for 1- lobe butterfly layout (prior art)

Figure 3   an embodiment for top loop-butterfly combination layout (prior art)

Figure 4   an embodiment for a bottom loop-butterfly combination layout (prior art)

Figure 5   an embodiment for a Four element loop-butterfly array layout (prior art)

Figure 6   an embodiment for a 3 lobe twisted loop layout

Figure 7   an embodiment for a 3- lobe twisted butterfly layout

Figure 8   illustrates an embodiment of a surface coil wrapped across a cylinder

Figure 9 a, b and C Illustrate SNR resulting from the different embodiments

DETAILED DESCRIPTION OF THE INVENTION

An embodiment of this invention combines traditional loop-butterfly array elements as illustrated in figure 3 and 4 whose z-alignment is modified as illustrated in figure 5, with stacked twisted loops and twisted butterfly elements as illustrated in figures 6 and 7. Higher order twisting which would result in >3 lobe twisted loops and >3 lobe twisted butterflys, which would generally make the individual lobes smaller and sacrifice SNR at the depth, d, but could also be used.   The twisted loop and twisted butterfly are offset with respect to the loop-butterfly pair along the long axis.

The dimensions of the loop/butterfly elements of Fig. 3,4,5 are chosen for maximum SNR at a particular depth away from the coil, then significant SNR gain occurs when the size of the lobes in the twisted loops and twisted butterflys are comparable. For maximum SNR at a depth =d, the dimensions of the loop and butterfly lobes would be chosen to be $x1=x2=z1=z2 \sim d$. These dimensions can vary by 10%-20% (and possibly more depending on other constraints). As illustrated in figure 5 the total length of the resulting four element loop butterfly array is $z3=2(z1)=2(z2)$.   As illustrated in Fig. 6, $z3$ should be chosen such that $z4 \sim d$ $(=z1)$ so that significant SNR gain will be achieved at depth d. For this twisted loop to be naturally decoupled from both loops of Fig. 5, $z5$ should be $\sim z1/2$ and the centre of the twisted loop (shown as $Z=0$) should be offset from the z-center of the loops of Fig.5 by $\sim z1/2$. The twisted loop is naturally isolated from the butterfly elements due to orthogonality as long as all coil elements have the same x and y center ($x=0$ here and all in the $y=0$ plane).

As illustrated in Fig. 7, $z3$ should be chosen such that $z6 \sim d$ $(=z2)$ so that significant SNR gain will be achieved at depth d. For this twisted butterfly to be naturally decoupled from both butterflys of Fig. 5, $z7$ should be $\sim z2/2$ and the centre of the twisted butterfly (shown as $Z=0$) should be offset from the z-center of the butterflys of Fig.5 by $\sim z2/2$. The twisted butterfly is naturally isolated from the loop and twisted loop elements due to orthogonality as long as all coil elements have the same x and y center ($x=0$ here and all in the $y=0$ plane).

Each of the coil elements (6 in this case) are then connected to separate preamplifiers (which may be of the low input impedance type) and then separate receivers. The MRI console would then reconstruct the phased array image into a single composite image with appropriate weighting of the images from these individual coil elements (6 in this example). Alternatively, signals from these array elements can be combined together in hardware to reduce the number of receivers required. This combination could be done before or after preamplification.

It is understood that the geometry of the coils could also be circular, hexagonal, rectangular, or diamond shapes or variations thereof. Furthermore, although the embodiment chosen to explain the invention is a surface array, the invention could also be applied to volume coils such as illustrated in figure 8.

RESULTS

By superimposing one twisted loop and one twisted butterfly on a four element loop butterfly surface Array of desired dimensions and symmetry, long axis SNR gains at the depth of interest of 20%-40% can be achieved between loop-butterfly elements and 7%-30% (as shown in figure 9a, 9b and 9c) at the position of the loop-butterfly elements.

REFERENCES

[1.] J.S. Hyde, A. Jesmanowicz, T.M. Grist, W. Froncisz, J.B. Kneeland, Quadrature Detection Surface Coil, MRM 4,1987, 179-184.

[2.] M. Ohliger, R. Greenman, C.A. McKenzie, D.K. Sodickson, Concentric Coil Arrays for Spatial Encoding in Parallel MRI, Proc. Intl. Soc. Mag. Reson. Med. 9 (2001) #21.

[3.] G.R. Duensing, U. Gotshal, F. Huang, S.B. King, "N-Dimensional Orthogonality of Volume Coils", Proceedings of the International Society for Magnetic Resonance in Medicine, 10th Annual Meeting, p.771, 2002.
Note to self: add two additional citations provided by Scott
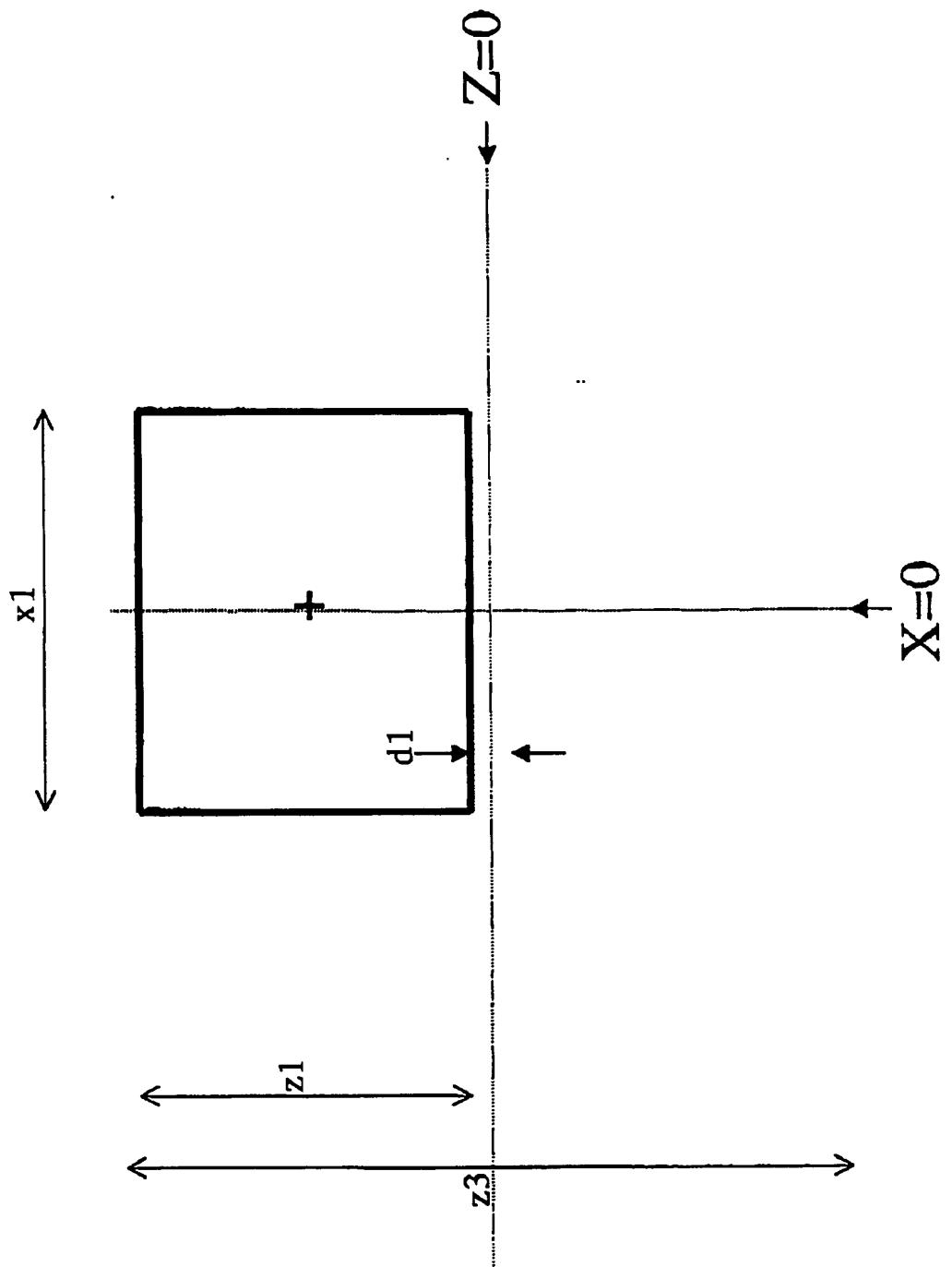
Fig. 1: 1-lobe Loop layout (prior art)
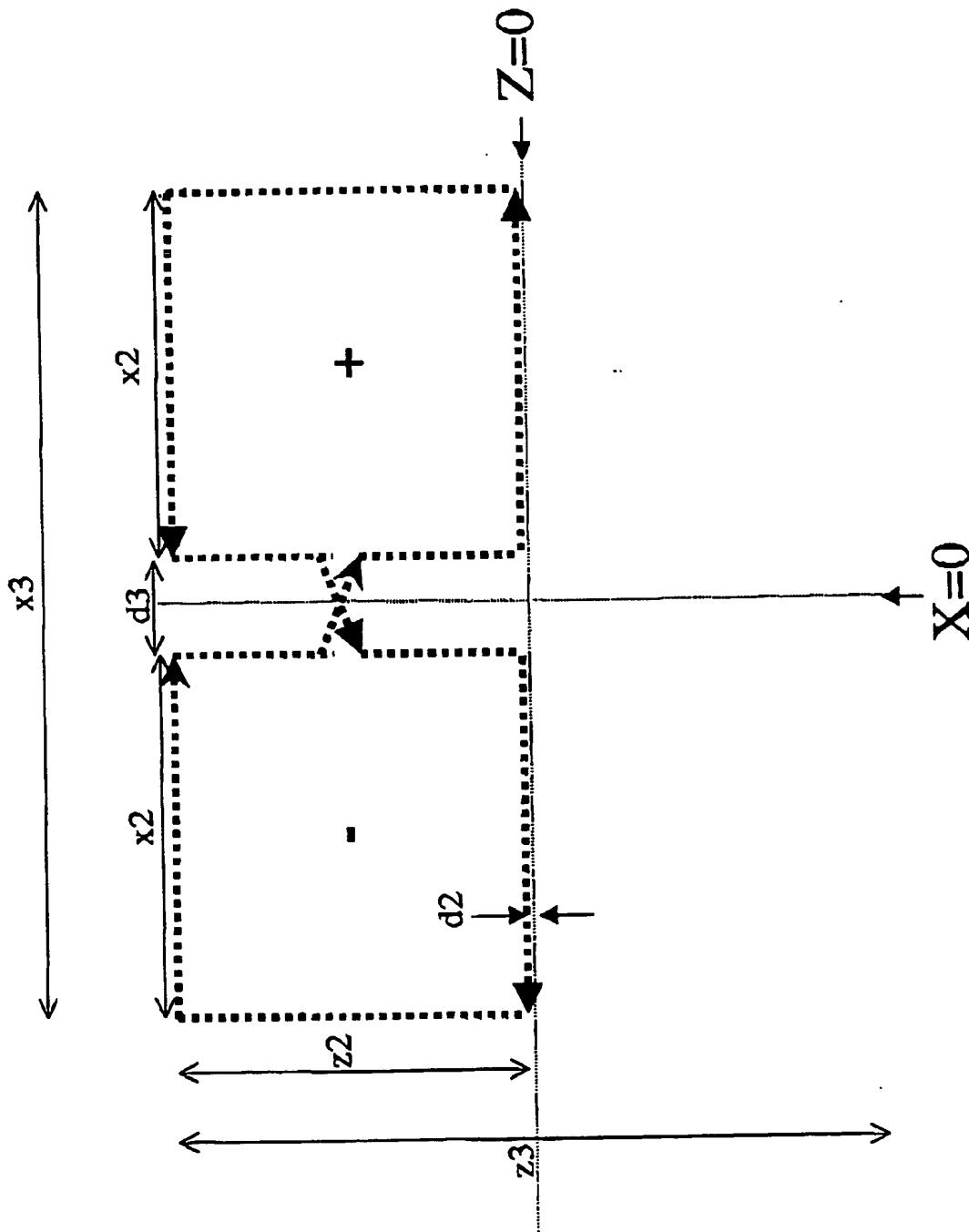
Fig. 2: 1-lobe Butterfly layout (prior art)
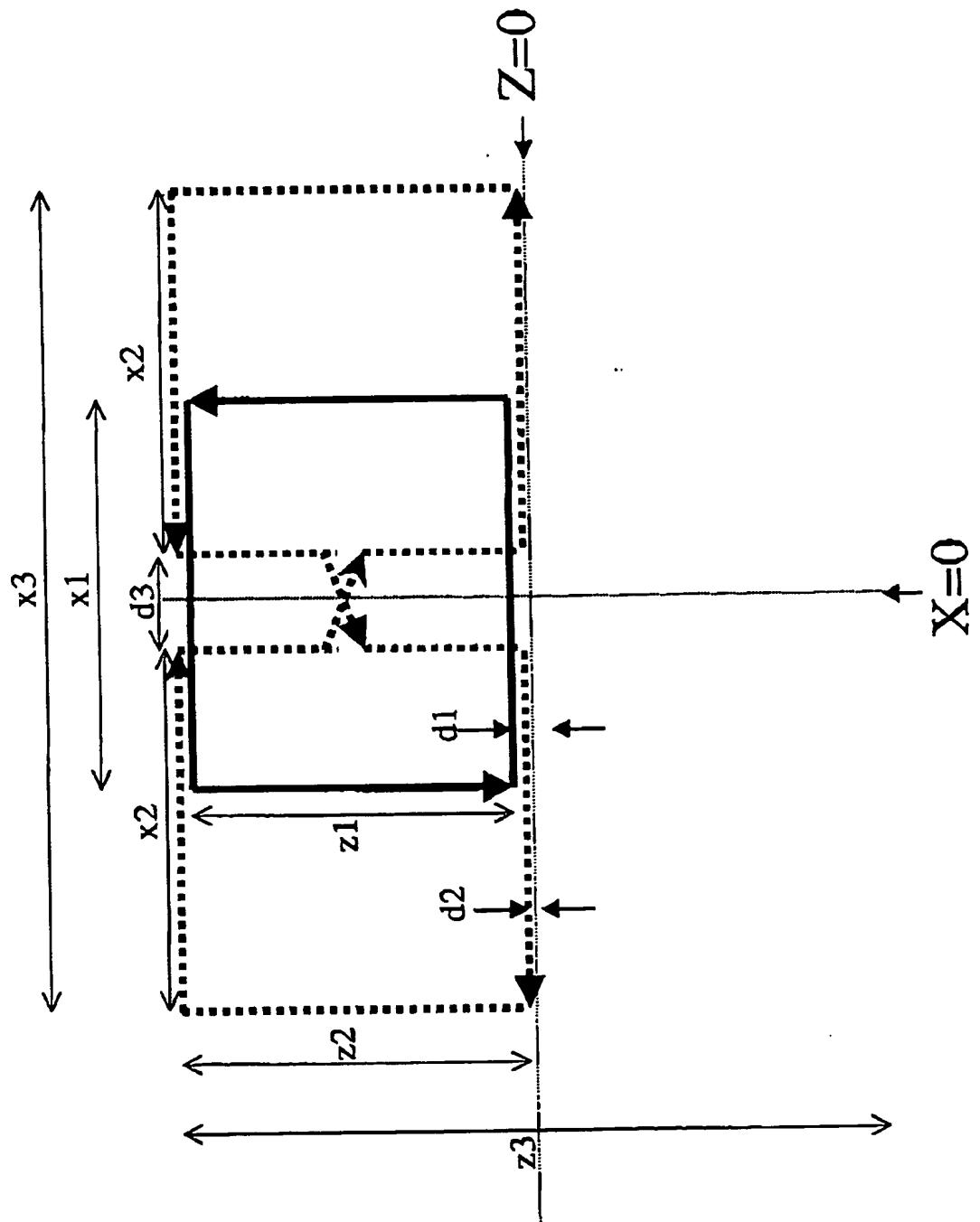
Fig. 3: Top Loop-Butterfly combination layout (prior art)
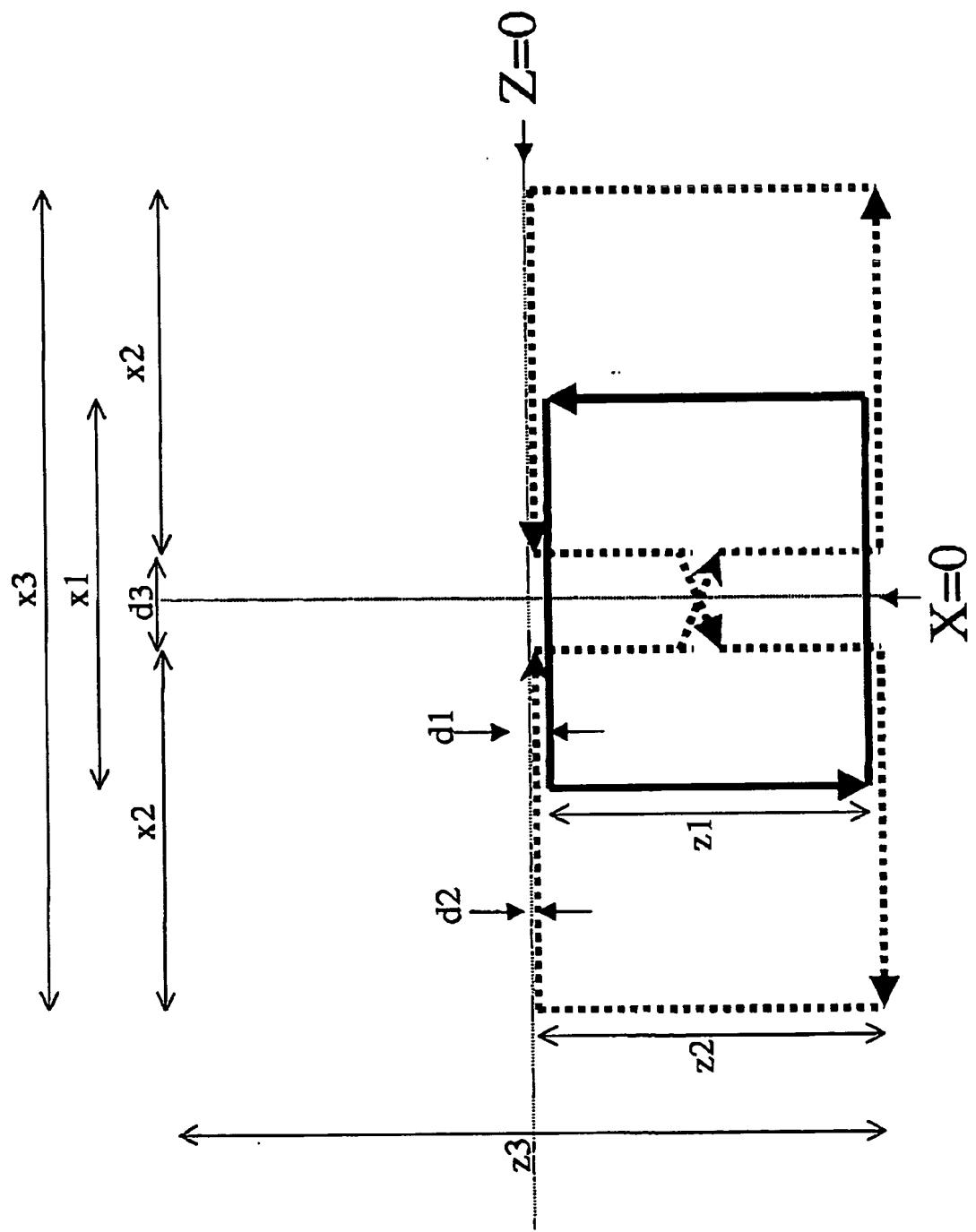
Fig. 4: Bottom Loop-Butterfly combination layout (prior art)
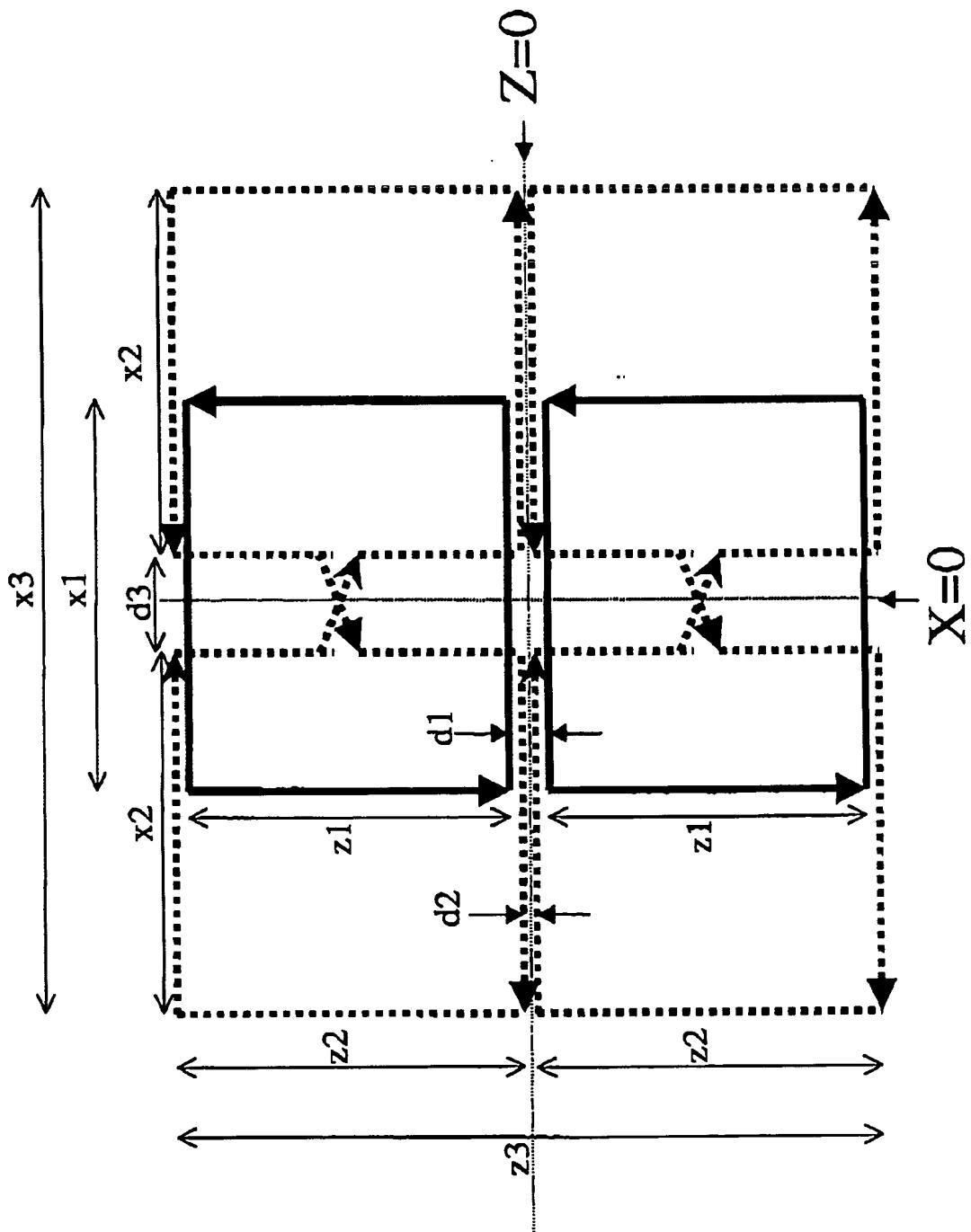
Fig. 5: Four element Loop-Butterfly Array layout
(Prior art)
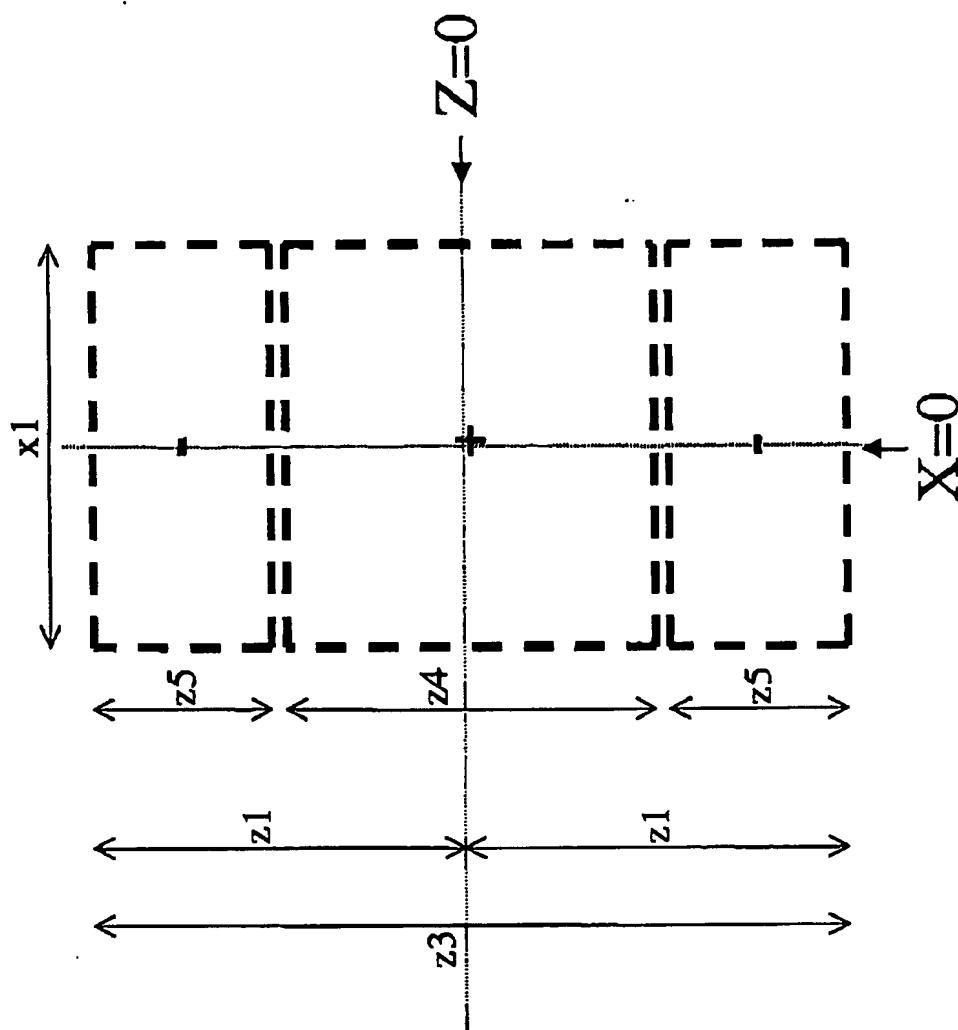
Fig. 6: 3-lobe Twisted loop layout

Fig. 7: 3-lobe Twisted Butterfly layout

--- Surface loops wrapped around Cylinder

___ 3-lobe twisted Loop

Note: center of 3-lobe twisted loop is in between surface loops

as in the surface (spine coil) arrangement!

— Scott B. K.   June 26, 2003
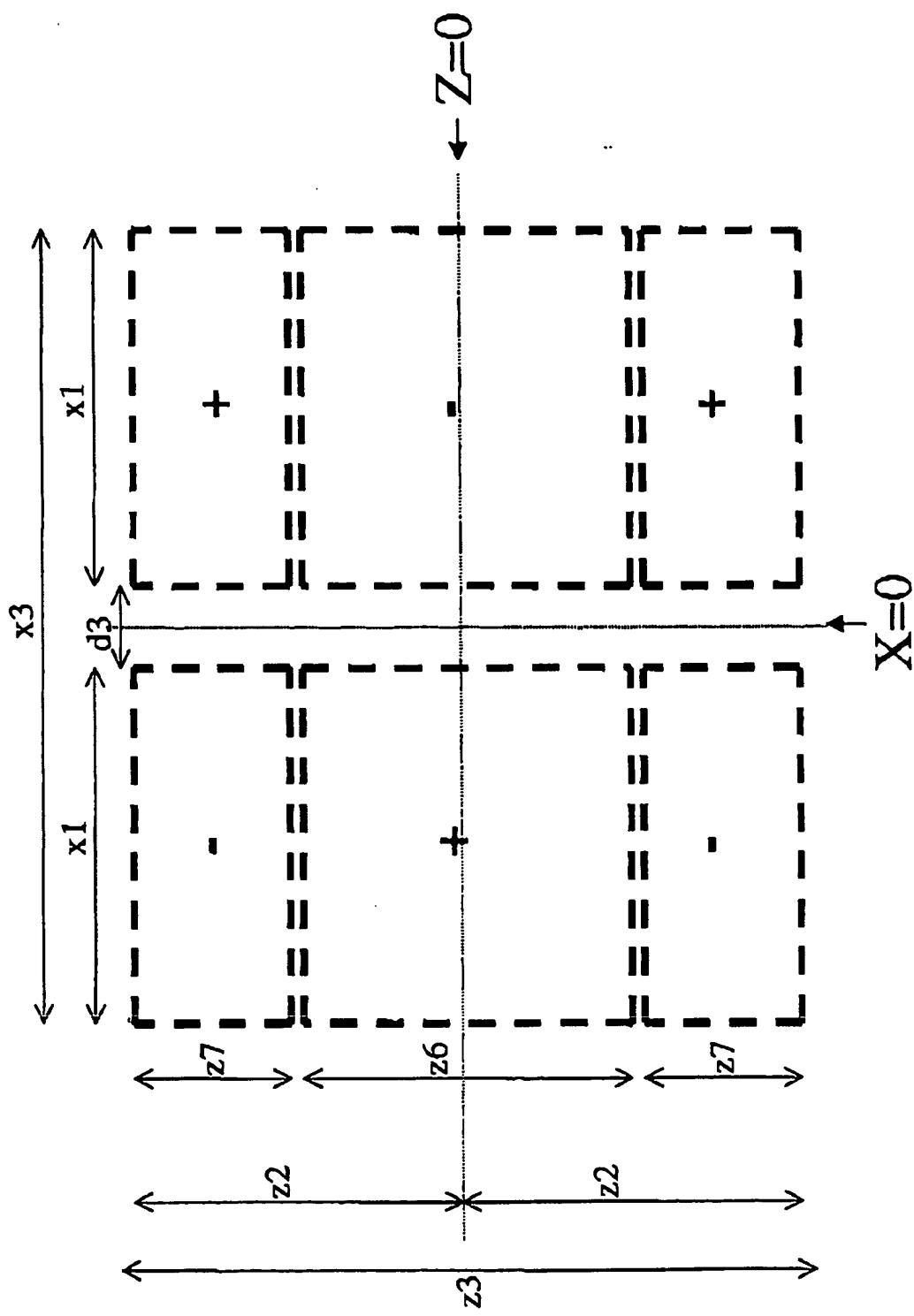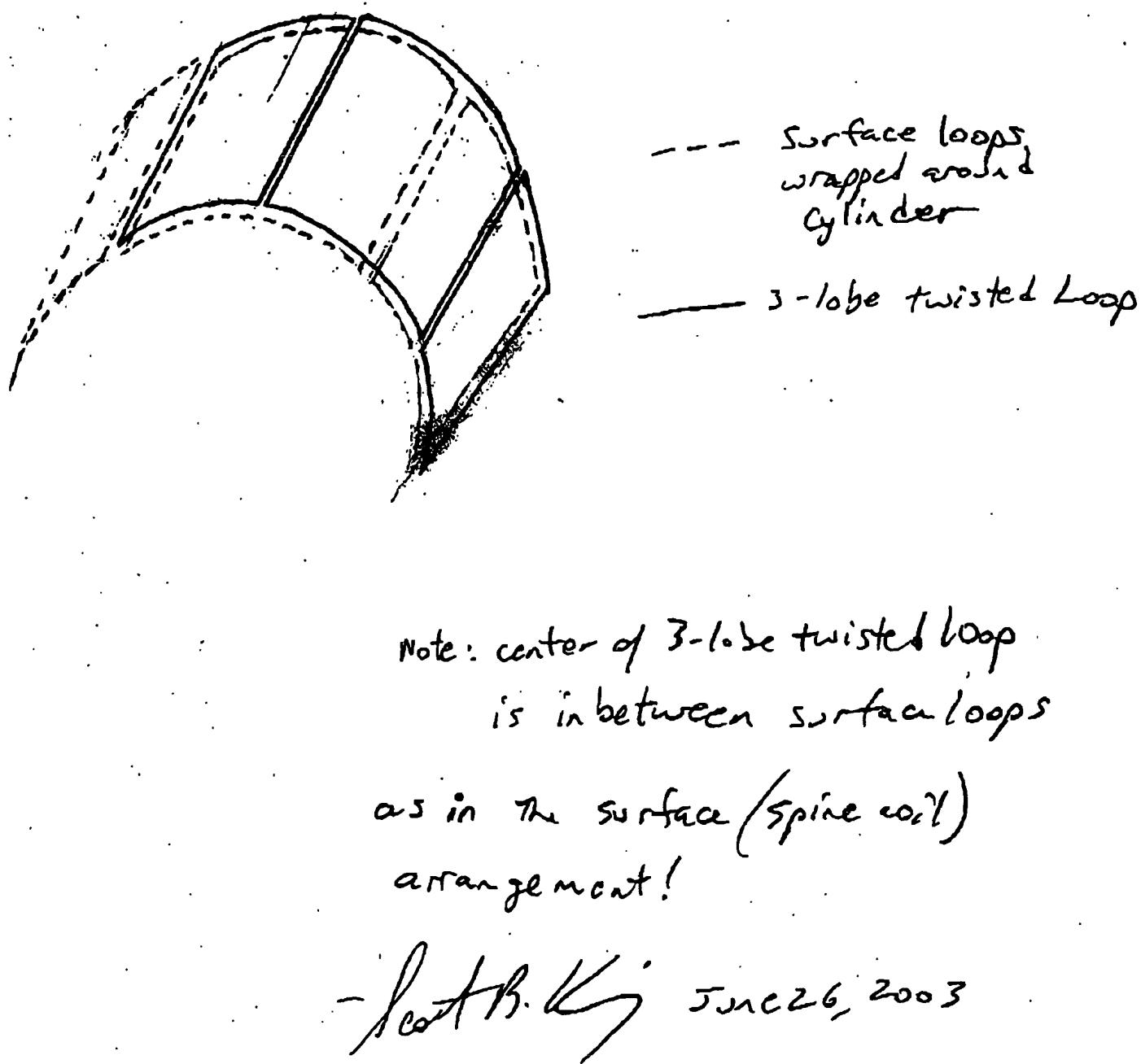
Figure 8.

SNR for the 6 elements and then the different combined SNR . Z-direction is Left-Right on the page. Y is up-down.
These are SNR images at X=0. The spine ranges from box #6 to box#13 from the top
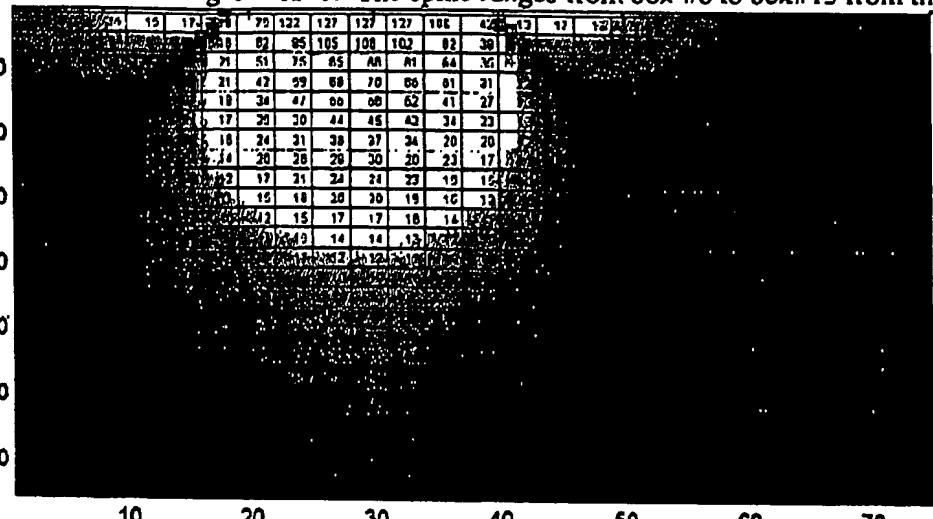
Element#1: Loop#1 (Fig.1 in prov.).
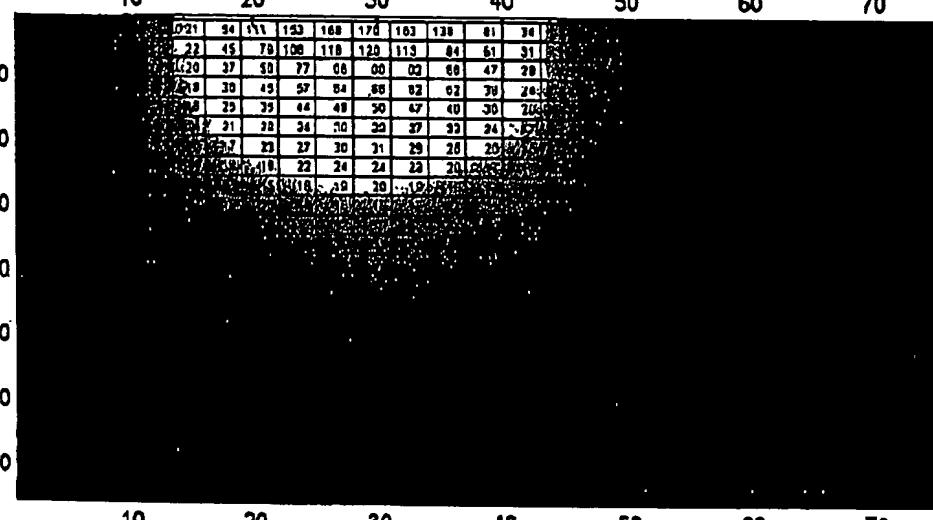
Element#2: Butterfly#1 (Fig.2 in prov.).
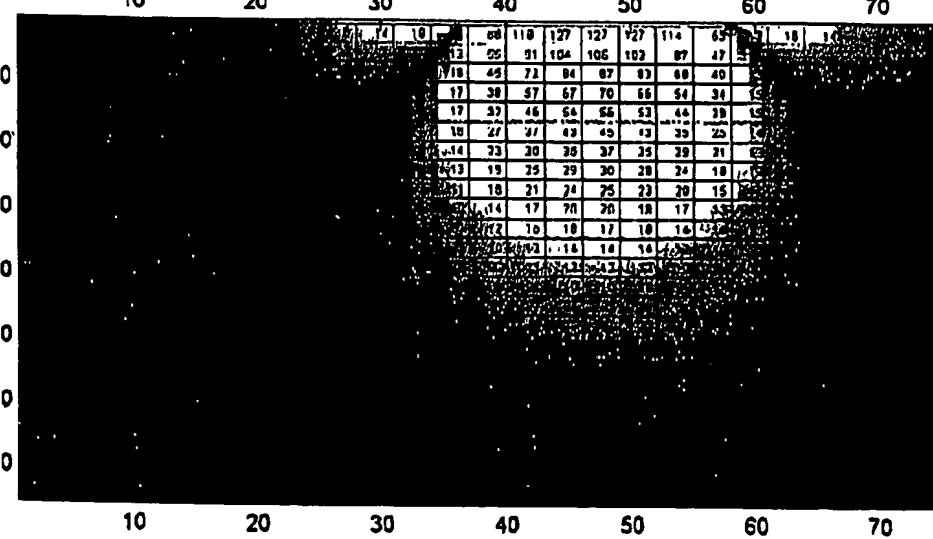
Element#3: Loop#2 (bottom loop of Fig.5 in prov.).

figure 9A
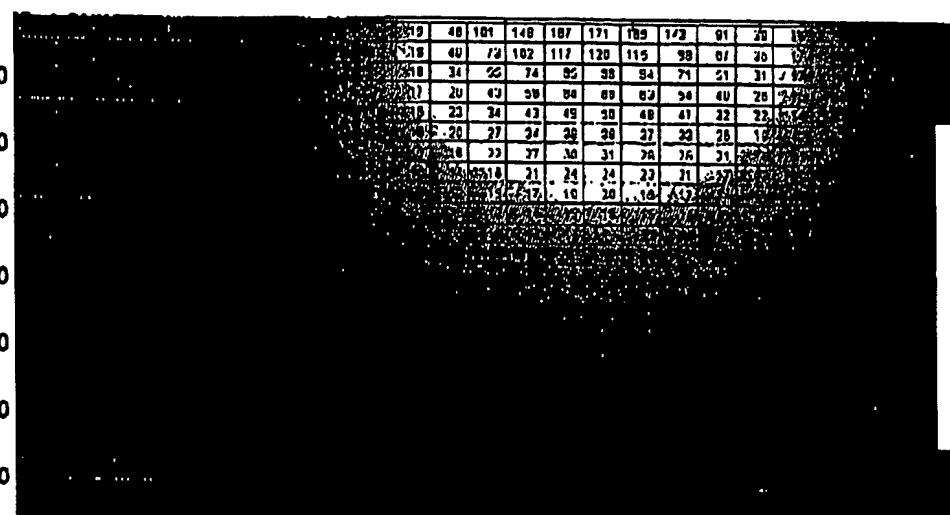
Element#4: Butterfly#2 (bottom butterfly of Fig.5 in prov.).
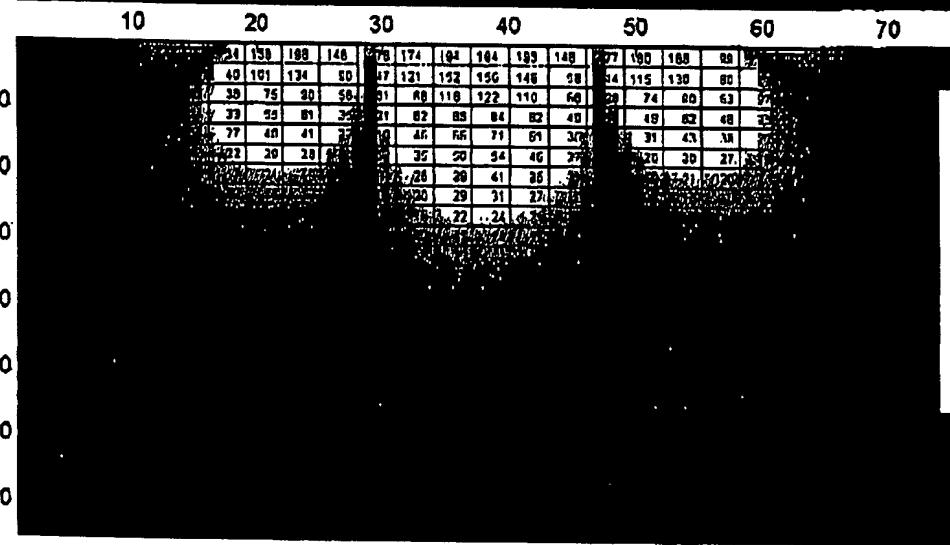
Element#5: Three lobe Twisted Loop (Fig.6 in prov.). Most gain at Z=0, but some SNR gained at Z=z1/2 and Z=z2/2. Here, is the total length of this element was not Z3, but say Z1, then the SNR depth would be much poorer.
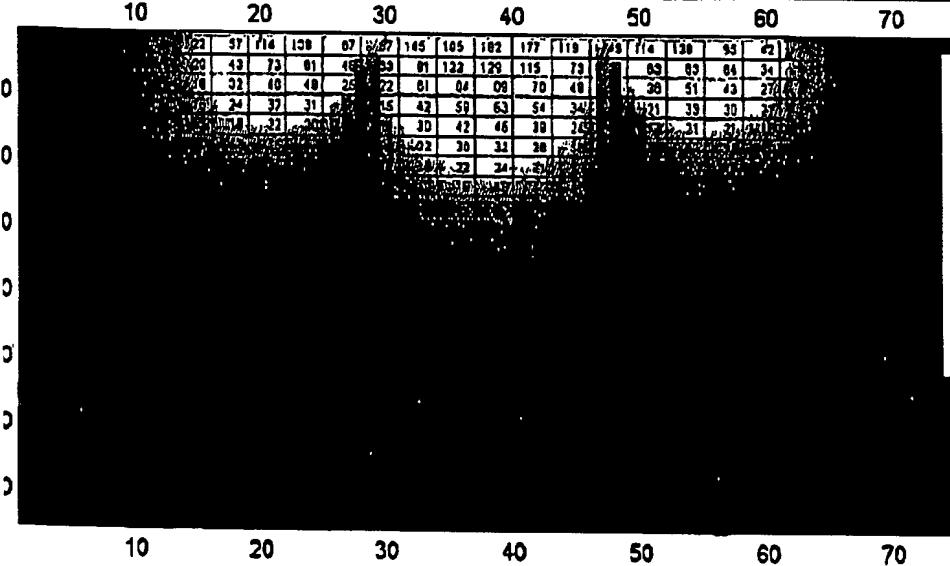
Element#6: Three lobe Twisted Butterfly (Fig.7 in prov.). Most gain at Z=0, but some SNR gained at Z=z1/2 and Z=z2/2

figure 9 B

Combined Array SNR images.
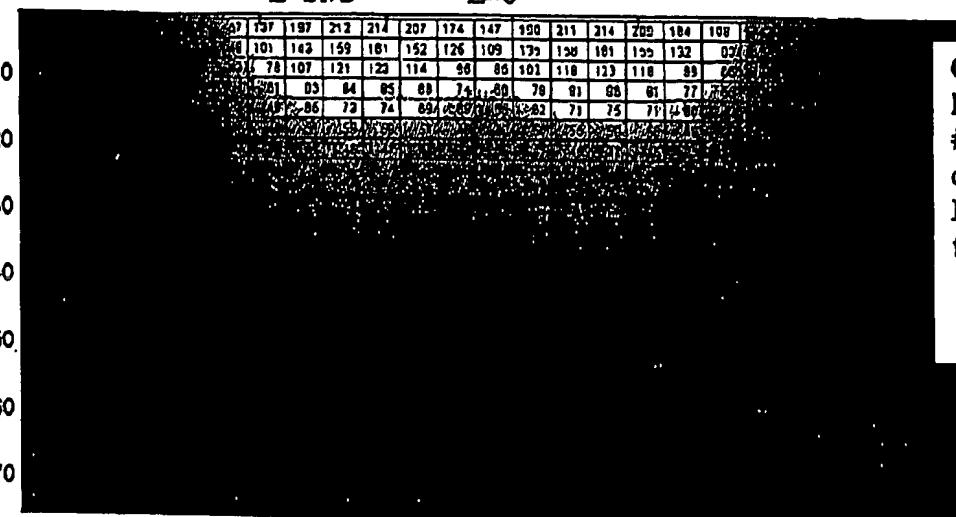
Combined Array SNR for only the loop/butterfly elements (Elements #1, #2, #3, and #4 only). This was considered as good as it gets by most MRI coil people. The spine ranges from box #6 to box#13 from the top
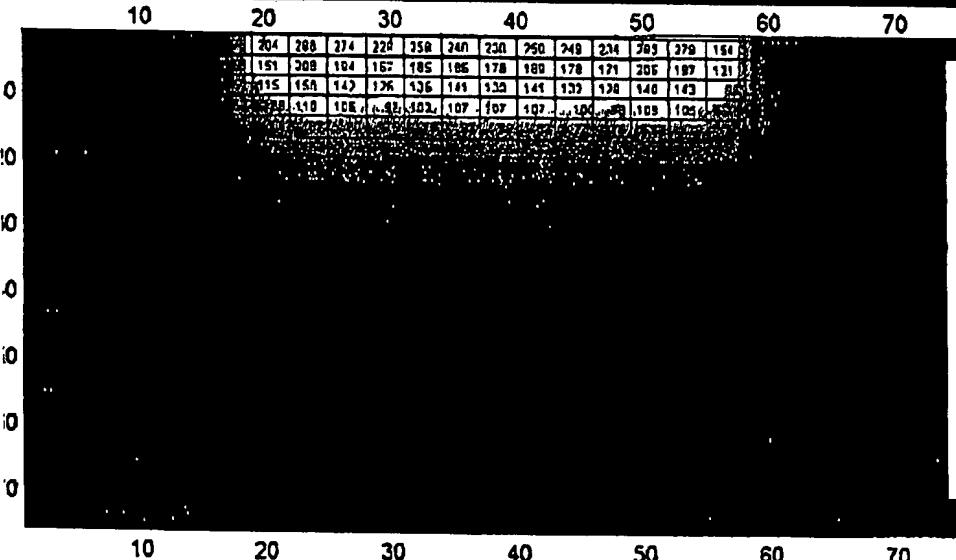
Combined Array SNR for the loop/butterfly elements (Elements #1, #2, #3, and #4) plus Element #5(ie adding twisted loop). The spine ranges from box #6 to box#13 from the top.
SNR gain over the loop/butterfly elements only (top figure on this page) is
Z=0: 41% at box6 and 7% at box13
Z=z1/2: 22% at box6 and 8% at box13
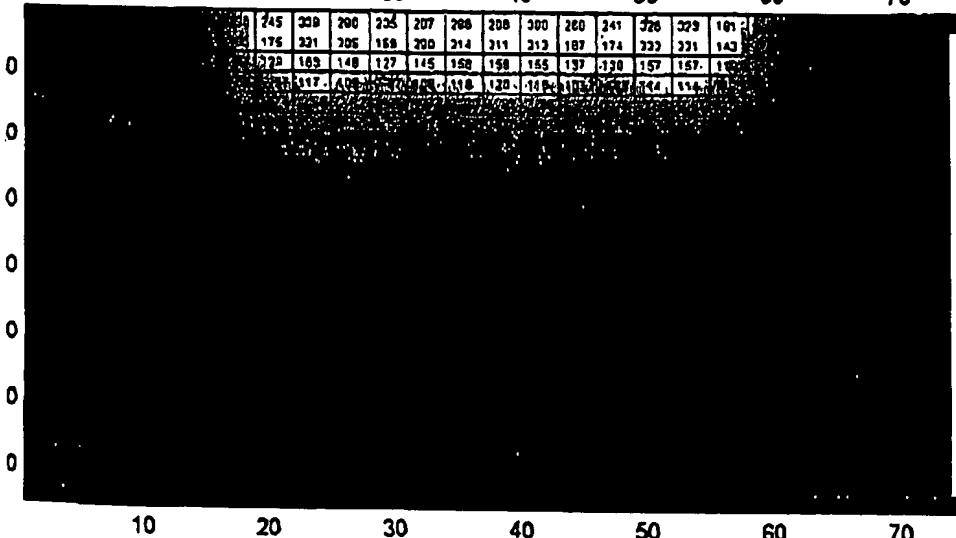
Combined Array SNR for the loop/butterfly elements (Elements #1, #2, #3, and #4) plus Element #5(ie adding twisted loop) and Element #6(twisted butterfly as well). The spine ranges from box #6 to box#13 from the top. SNR gain over the loop/butterfly elements only (top figure on this page) is
Z=0: 52% at box6 and 14% at box13
Z=z1/2: 27% at box6 and 8% at box13

Figure 9c.

Document made available under the Patent Cooperation Treaty (PCT)

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